Event Rates at the Galactic Center: a UKIRT near-IR Survey

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UKIRT microlensing team:

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Microlensing 21 Flashback

Yossi introduced the survey last year:

- Initial analysis of a few low-b fields, ~5% of total dataset
- Discovery of 5 highly-extinguished low-b microlensing events
- Preliminary estimate of the event rate at $b \approx 1^\circ$
UKIRT telescope:
- 3.8m NIR telescope @ Mauna Kea
- Average seeing ~0.8"

WFCAM camera:
- Four NIR detectors
- 0.4”/pixel
- Four exposures covers 0.75 sq.deg
- Available filters – ZYJHK
Scientific goals of UKIRT survey

**NIR event rate as a function of \((l,b)\):**

- Crucial for \textit{WFIRST} field optimization
- Combined with dust models \(\rightarrow\) Galactic structure

**Event timescale as a function of \((l,b)\):**

- Bulge-bulge events are expected to be shorter (Gould 1995)

**NIR coverage of events:**

- Source color - for Einstein radius (with finite source effects)
- NIR source flux - for future AO lens flux measurements

**New science:**

- High cadence (daily) observations of unexplored regions (Galactic center).
UKIRT 2015-2016 microlensing surveys

2015 survey – *Spitzer*:
- Area: 3.4 deg$^2$
- Duration: 39 nights
- Cadence: 5 epochs/night
- Total epochs per field: ~145
- Filter: $H$

2016 survey – *K2C9*:
- Area: 6.0 deg$^2$
- Duration: 91 nights
- Cadence: 2-3 epochs/night
- Total epochs per field: ~160
- Filter: $H$

Shvartzvald et al. 2017
UKIRT 2017(-2019) microlensing surveys

2017:
- Area: 10.5 deg$^2$
- Dates: 20/Apr (4/May) – 30/Aug
- Duration: 133 nights
- Cadence: 1-3 epochs/night
- Filters: $H / K$
UKIRT 2017(-2019) microlensing surveys

**2017:**
- Area: 10.5 deg$^2$
- Dates: 20/Apr (4/May) – 30/Aug
- Duration: 133 nights
- Cadence: 1-3 epochs/night
- Filters: $H / K$

Figure: Sumi & Penny 2016
Photometry

Photometry methods:

1. Soft-edged aperture photometry by CASU (Hodgkin et al. 2009)
   - Several apertures: 0.5”, 0.7”, 1”, 1.4”….
   - 2MASS calibrated
   - Spatial distortion corrected

2. PSF photometry using SExtractor (Bertin & Arnouts 1996) and PSFEx (Bertin 2011)
   - ~2MASS calibrated

3. DIA photometry for specific events using pySis (Albrow et. al. 2009)
**Photometry – CASU vs. PSF**

**Precision:**
- Reaching <2% level
- CASU is better at $H<14.5$

**Source detection:**
- Number of sources similar for $H<15$
- PSF much better for faint sources
- In total, almost twice as many sources with PSF
- Red clump excess around $H=13.5$
Event detection

- Event finder similar to KMT (Kim et al. 2018), based on a 2-D \((t_0, t_{\text{eff}})\) grid search
- Conservative detection threshold: \(\Delta \chi^2 > 500\)
- Challenges: outliers, variable stars, long events

<table>
<thead>
<tr>
<th>Season</th>
<th>Location</th>
<th>Lightcurves</th>
<th>Candidates</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>North</td>
<td>6.7M</td>
<td>563</td>
</tr>
<tr>
<td>2016</td>
<td>South</td>
<td>11.3M</td>
<td>845</td>
</tr>
<tr>
<td>2017</td>
<td>N+S+Central</td>
<td>18.1M</td>
<td>3352</td>
</tr>
</tbody>
</table>
For now we are using a python-based GUI to identify microlensing events among the candidate lightcurves by eye.

We are implementing a machine-learning classification system. Current results with a random forest classifier (cf. Wyrzykowski+ 2015) are promising (false positive/negative rates below 20%), but are limited by the information content within the chosen set of lightcurve features. New metrics need to be included.
UKIRT microlensing events

2015:
• North – 13 (4 UKIRT-only)

2016:
• South – 53 (16)

2017:
• North – 16 (8)
• Central – 69 (68)
• South – 26 (16)
Image level injection/recovery:

- Event injections – using PSF templates from PSFEx
- Run through the full pipeline (PSF photometry + event detection)

Detection efficiency – Future work

Savannah Jacklin
PhD student
Vanderbilt
Detection efficiency

Lightcurve-level detection simulations:

Northern fields

Central fields
Near-IR event rate

Source density

Detection efficiency

Events

Relative Detection Efficiencies

- 2017_c1_1
- 2016_12
- 2016_82
- 2017_s1_1
- 2017_s5_1
- 2017_n2_1
- 2015_32
Near-IR event rate

**Preliminary results:**

1. High event rate in the central fields
2. No excess of events in the northern bulge
Additional Science

2015:
• A massive remnant in wide binary:
  OGLE-2015-1285 (Shvartzvald et al. 2015)

2016:
• Planets:
  MOA-2016-227 (Koshimoto et al. 2017)
  OGLE-2016-0163 (Han et al. 2017)
  OGLE-2016-1190 (Ryu et al. submitted)
  OGLE-2016-0241 (Poleski et al. in prep.)

2017:
• Planet:
  OGLE-2017-0173 (Hwang et al. 2017)
UKIRT-2017-BLG-001b

Shvartzvald et al. 2018
Summary

• 2017 survey of the galactic center (inner 1°) finds a high microlensing rate

• 2018 survey will repeat these fields, adding baseline and improving statistics

• We will meanwhile improve the analysis
  - lower detection thresholds
  - machine learning for event classification
  - injection/recovery for detection efficiency

• Variable extinction is problematic (see next talk)

• Lightcurves are publicly available in the NASA Exoplanet Archive (see next next talk) https://exoplanetarchive.ipac.caltech.edu/docs/UKIRTMission.html https://exoplanetarchive.ipac.caltech.edu/cgi-bin/TblSearch/nph-tblSearchInit?app=ExoTbs&config=ukirttimeseries